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Kobayashi et al.

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(45) **Date of Patent: Aug. 4, 2015**

(54) **COMPUTER-READABLE RECORDING MEDIUM IN WHICH THERMAL HYDRAULIC SIMULATION PROGRAM IS STORED, THERMAL HYDRAULIC SIMULATING DEVICE, AND METHOD FOR THERMAL HYDRAULIC SIMULATION**

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G06F 7/60 (2006.01)
G06F 17/10 (2006.01)
G06F 17/50 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/5018*** (2013.01); *G06F 2217/80* (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/5009; G06F 2217/80
USPC 703/2
See application file for complete search history.

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(74) *Attorney, Agent, or Firm* — Fujitsu Patent Center

(57) **ABSTRACT**

In the event of modifying analysis condition, after the simulation of a first time step carried out when the analysis condition is modified finishes and before the simulation of a second time step next after the first step starts, the modified analysis condition is referred and the simulation based on the modified analysis condition is carried out in the next time step.

18 Claims, 11 Drawing Sheets

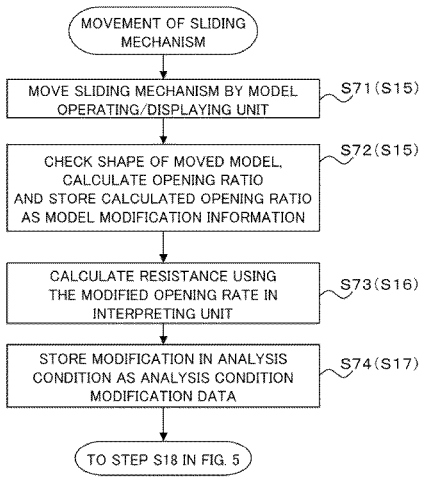

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FIG. 1

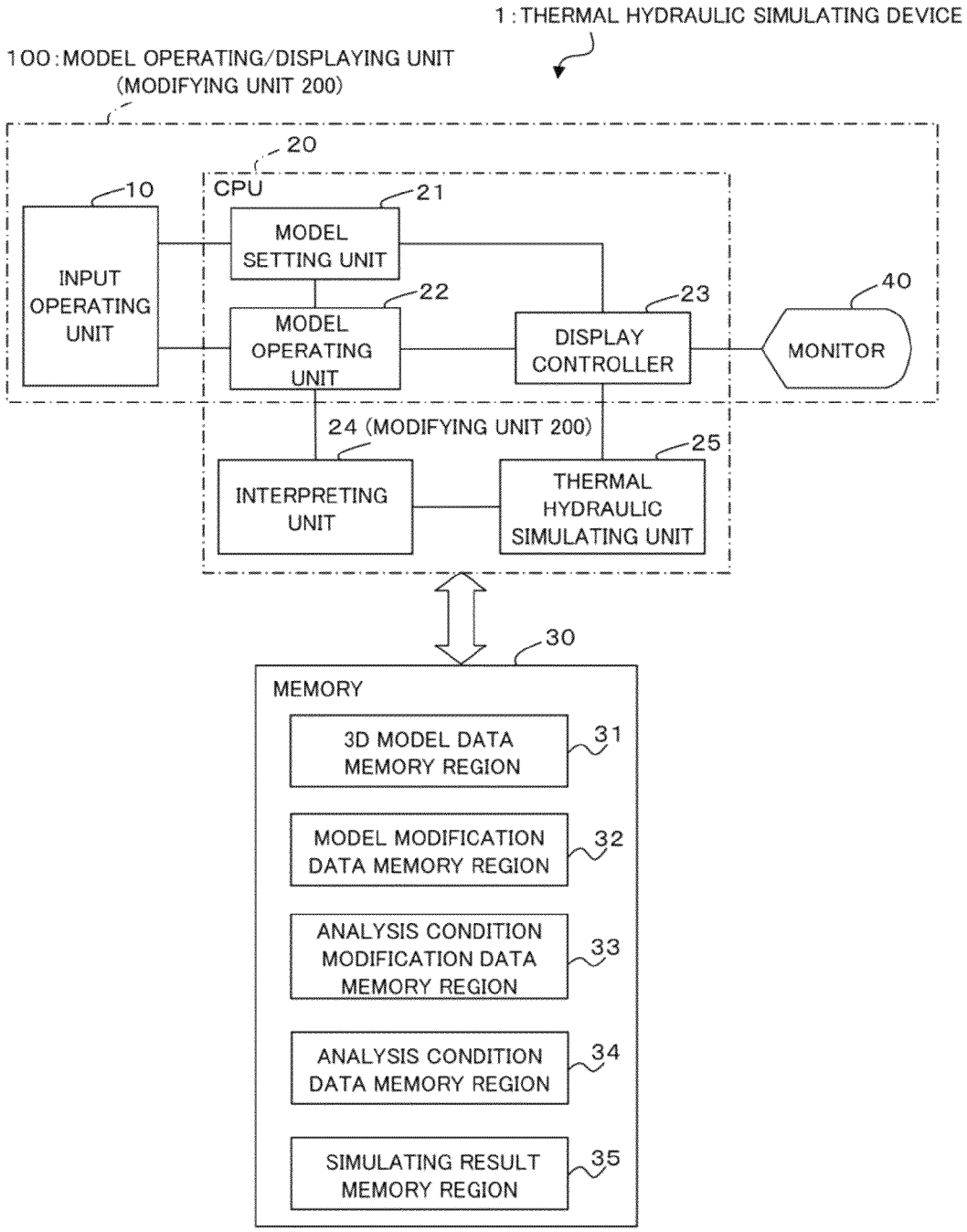

1 : THERMAL HYDRAULIC SIMULATING DEVICE
100 : MODEL OPERATING/DISPLAYING UNIT
(MODIFYING UNIT 200)
20
CPU
10
INPUT OPERATING UNIT
21
MODEL SETTING UNIT
22
MODEL OPERATING UNIT
23
DISPLAY CONTROLLER
40
MONITOR
24 (MODIFYING UNIT 200)
INTERPRETING UNIT
25
THERMAL HYDRAULIC SIMULATING UNIT
30
MEMORY
3D MODEL DATA MEMORY REGION
31
MODEL MODIFICATION DATA MEMORY REGION
32
ANALYSIS CONDITION MODIFICATION DATA MEMORY REGION
33
ANALYSIS CONDITION DATA MEMORY REGION
34
SIMULATING RESULT MEMORY REGION
35

FIG. 2

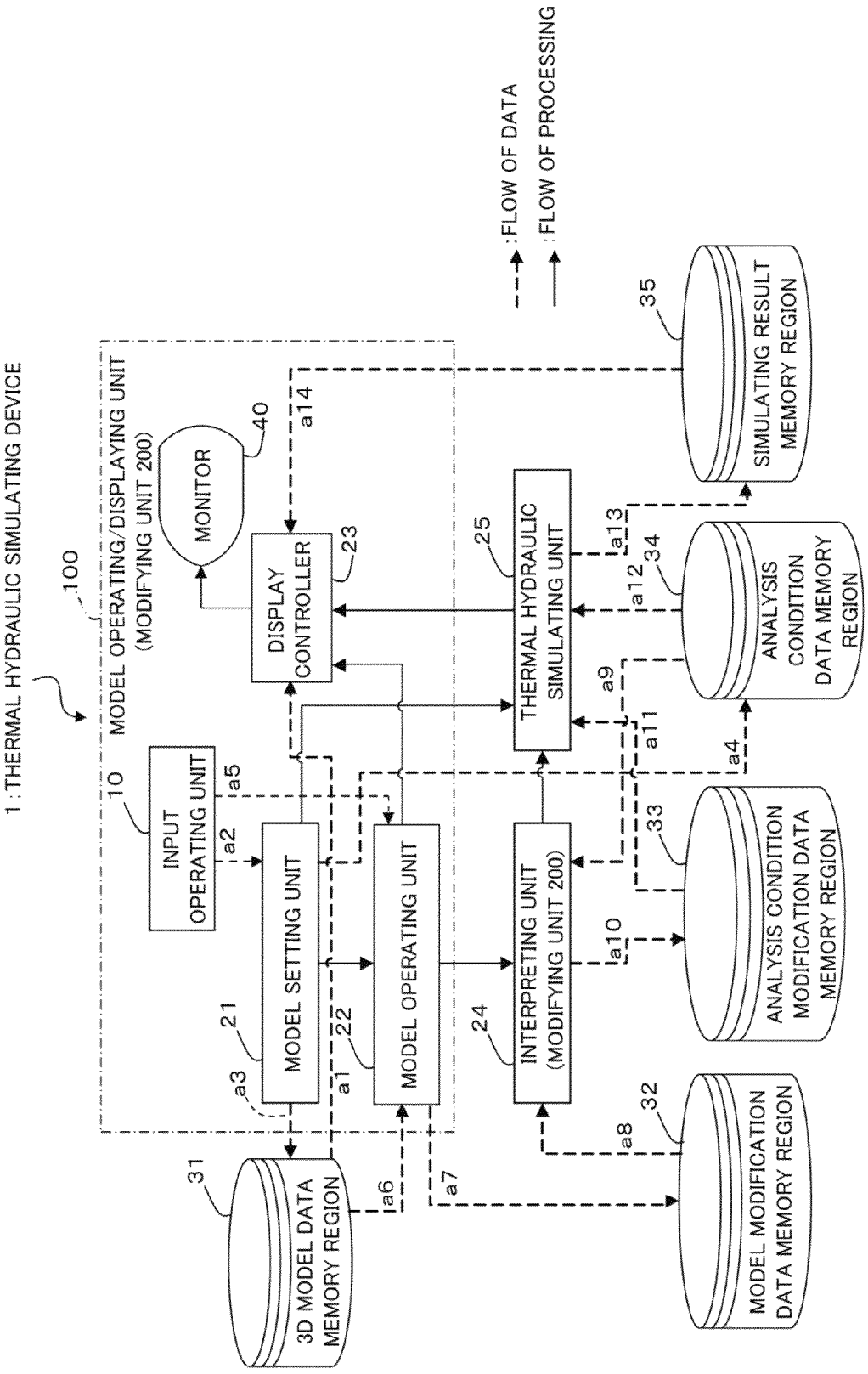

1 : THERMAL HYDRAULIC SIMULATING DEVICE
100
MODEL OPERATING/DISPLAYING UNIT (MODIFYING UNIT 200)
10
INPUT OPERATING UNIT
MODEL SETTING UNIT
MODEL OPERATING UNIT
INTERPRETING UNIT (MODIFYING UNIT 200)
DISPLAY CONTROLLER
THERMAL HYDRAULIC SIMULATING UNIT
MONITOR
3D MODEL DATA MEMORY REGION
MODEL MODIFICATION DATA MEMORY REGION
ANALYSIS CONDITION MODIFICATION DATA MEMORY REGION
ANALYSIS CONDITION DATA MEMORY REGION
SIMULATING RESULT MEMORY REGION
: FLOW OF DATA
: FLOW OF PROCESSING

FIG. 3A

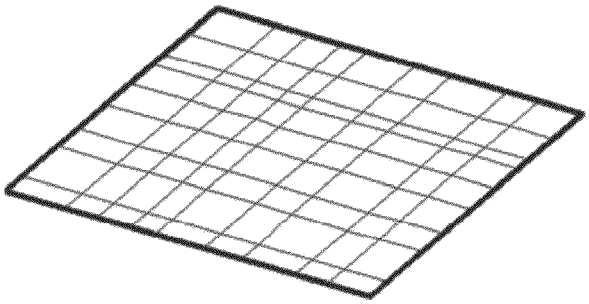


FIG. 3B

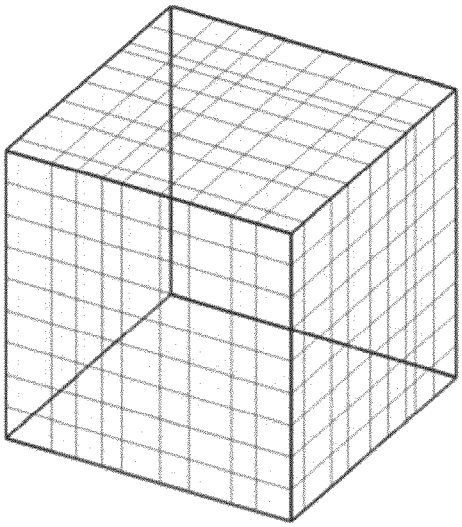


FIG. 4

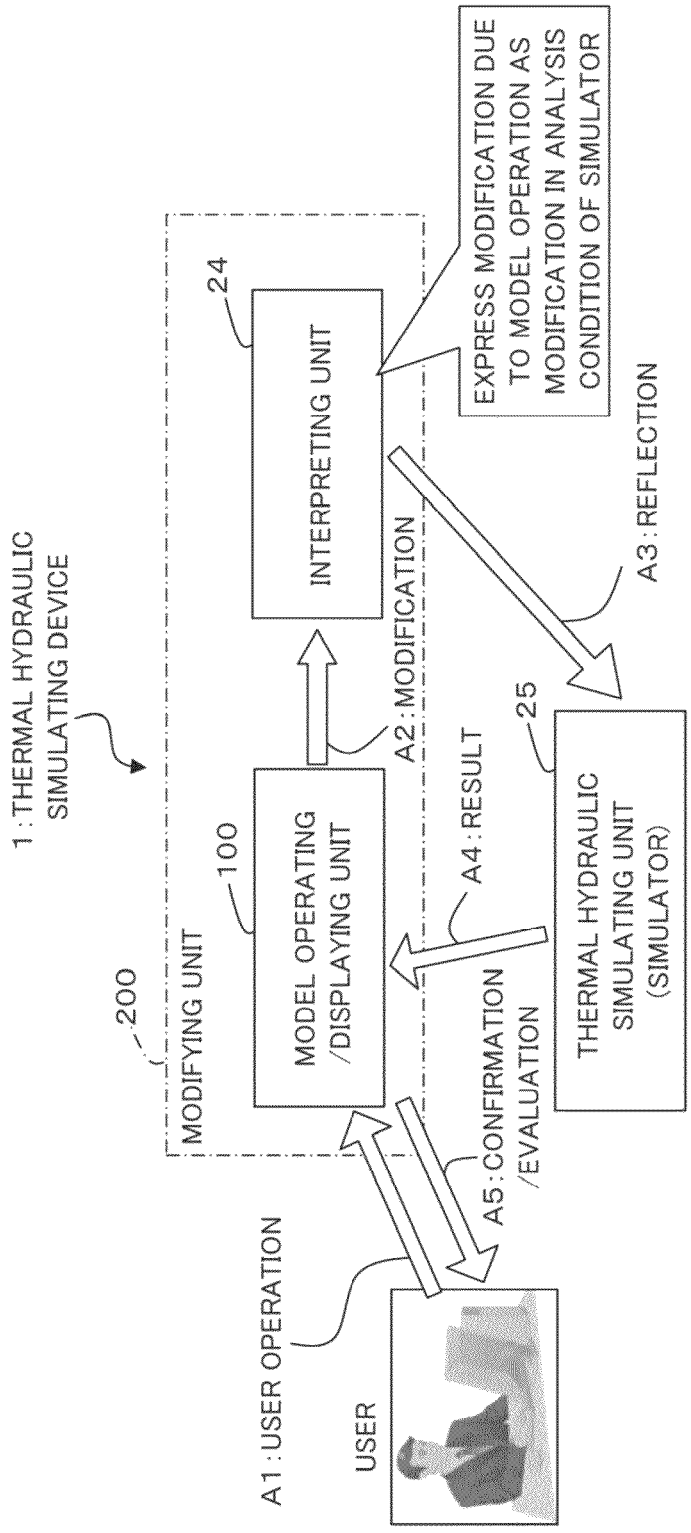

1 : THERMAL HYDRAULIC SIMULATING DEVICE
MODIFYING UNIT
200
MODEL OPERATING /DISPLAYING UNIT
100
INTERPRETING UNIT
24
THERMAL HYDRAULIC SIMULATING UNIT (SIMULATOR)
25
EXPRESS MODIFICATION DUE TO MODEL OPERATION AS MODIFICATION IN ANALYSIS CONDITION OF SIMULATOR
A1 : USER OPERATION
A2 : MODIFICATION
A3 : REFLECTION
A4 : RESULT
A5 : CONFIRMATION /EVALUATION
USER

FIG. 5

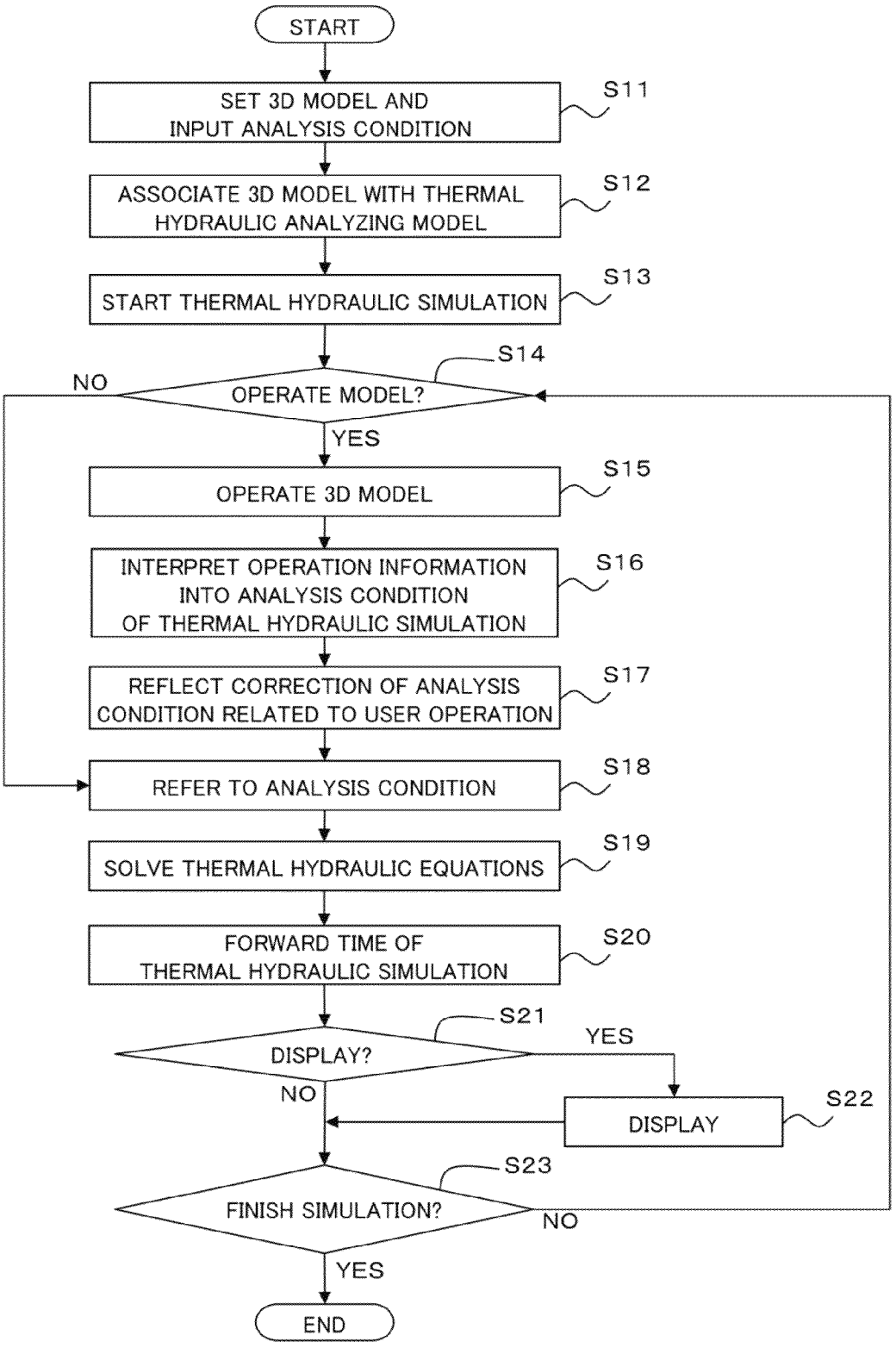

START
SET 3D MODEL AND INPUT ANALYSIS CONDITION
S11
ASSOCIATE 3D MODEL WITH THERMAL HYDRAULIC ANALYZING MODEL
S12
START THERMAL HYDRAULIC SIMULATION
S13
S14
NO
OPERATE MODEL?
YES
OPERATE 3D MODEL
S15
INTERPRET OPERATION INFORMATION INTO ANALYSIS CONDITION OF THERMAL HYDRAULIC SIMULATION
S16
REFLECT CORRECTION OF ANALYSIS CONDITION RELATED TO USER OPERATION
S17
REFER TO ANALYSIS CONDITION
S18
SOLVE THERMAL HYDRAULIC EQUATIONS
S19
FORWARD TIME OF THERMAL HYDRAULIC SIMULATION
S20
S21
DISPLAY?
YES
NO
DISPLAY
S22
S23
FINISH SIMULATION?
NO
YES
END

FIG. 6

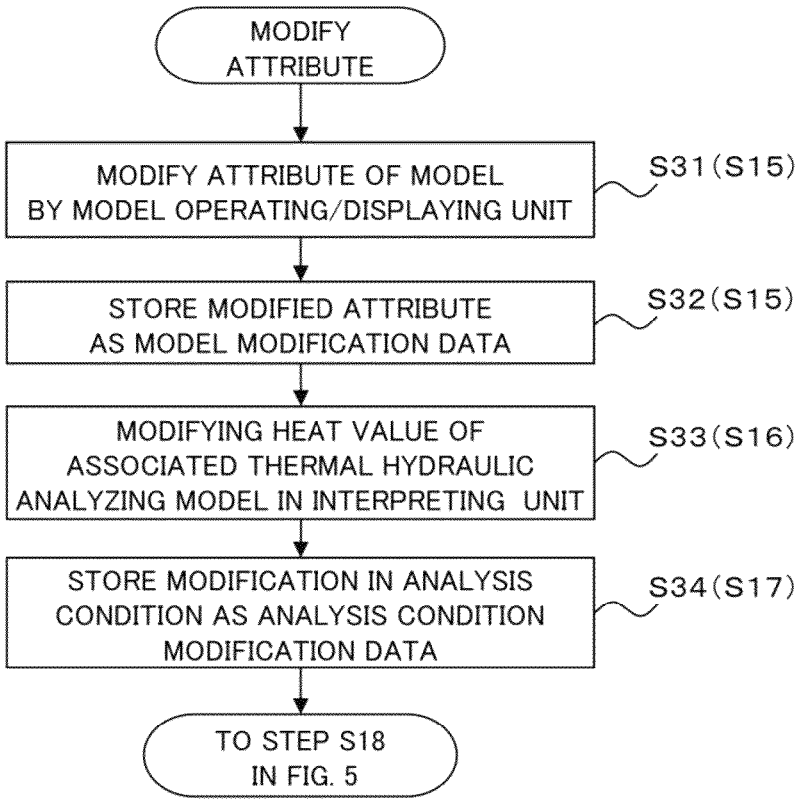

MODIFY ATTRIBUTE
MODIFY ATTRIBUTE OF MODEL BY MODEL OPERATING/DISPLAYING UNIT
S31(S15)
STORE MODIFIED ATTRIBUTE AS MODEL MODIFICATION DATA
S32(S15)
MODIFYING HEAT VALUE OF ASSOCIATED THERMAL HYDRAULIC ANALYZING MODEL IN INTERPRETING UNIT
S33(S16)
STORE MODIFICATION IN ANALYSIS CONDITION AS ANALYSIS CONDITION MODIFICATION DATA
S34(S17)
TO STEP S18 IN FIG. 5

FIG. 7

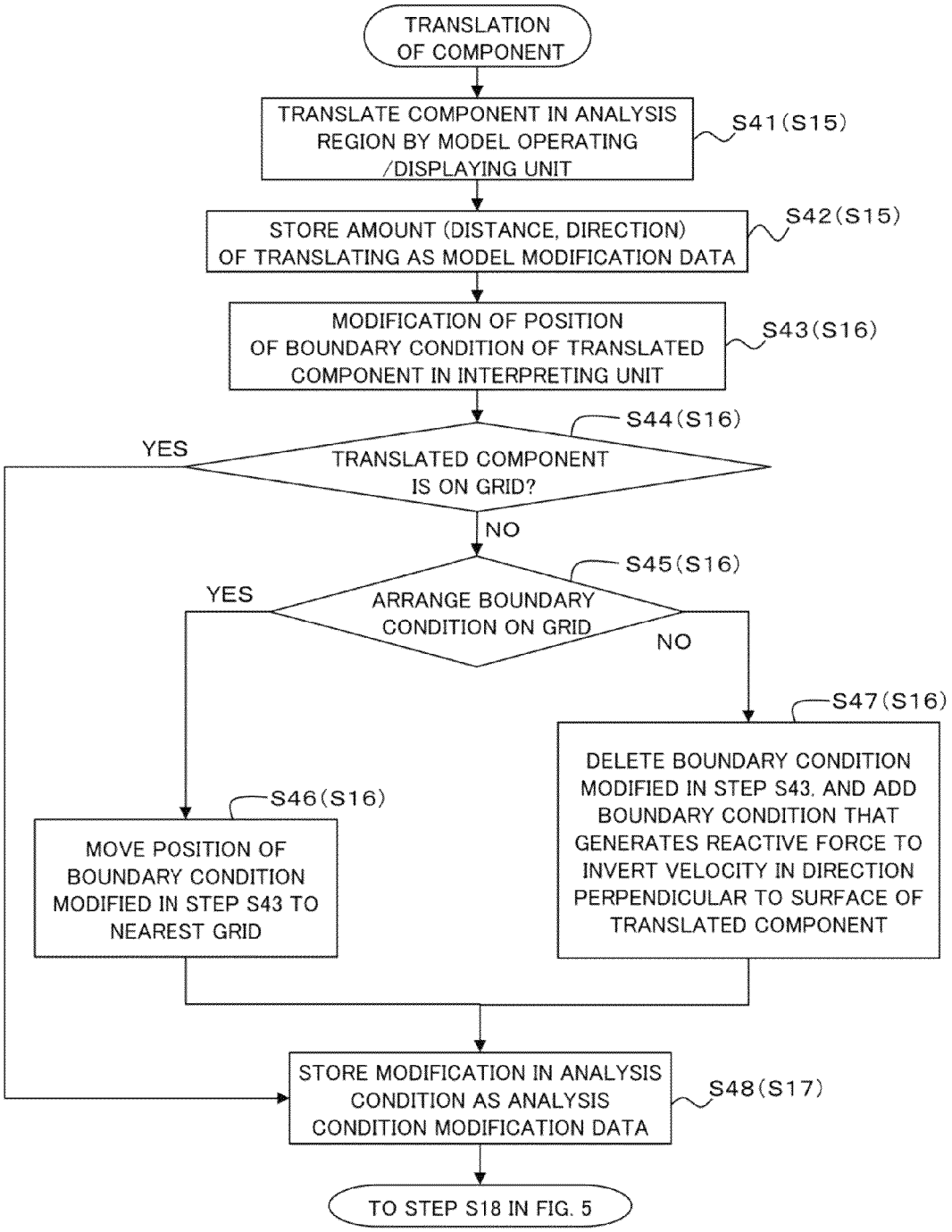

TRANSLATION OF COMPONENT
TRANSLATE COMPONENT IN ANALYSIS REGION BY MODEL OPERATING /DISPLAYING UNIT
S41(S15)
STORE AMOUNT (DISTANCE, DIRECTION) OF TRANSLATING AS MODEL MODIFICATION DATA
S42(S15)
MODIFICATION OF POSITION OF BOUNDARY CONDITION OF TRANSLATED COMPONENT IN INTERPRETING UNIT
S43(S16)
S44(S16)
TRANSLATED COMPONENT IS ON GRID?
YES
NO
S45(S16)
ARRANGE BOUNDARY CONDITION ON GRID
YES
NO
S46(S16)
MOVE POSITION OF BOUNDARY CONDITION MODIFIED IN STEP S43 TO NEAREST GRID
S47(S16)
DELETE BOUNDARY CONDITION MODIFIED IN STEP S43, AND ADD BOUNDARY CONDITION THAT GENERATES REACTIVE FORCE TO INVERT VELOCITY IN DIRECTION PERPENDICULAR TO SURFACE OF TRANSLATED COMPONENT
STORE MODIFICATION IN ANALYSIS CONDITION AS ANALYSIS CONDITION MODIFICATION DATA
S48(S17)
TO STEP S18 IN FIG. 5

FIG. 8

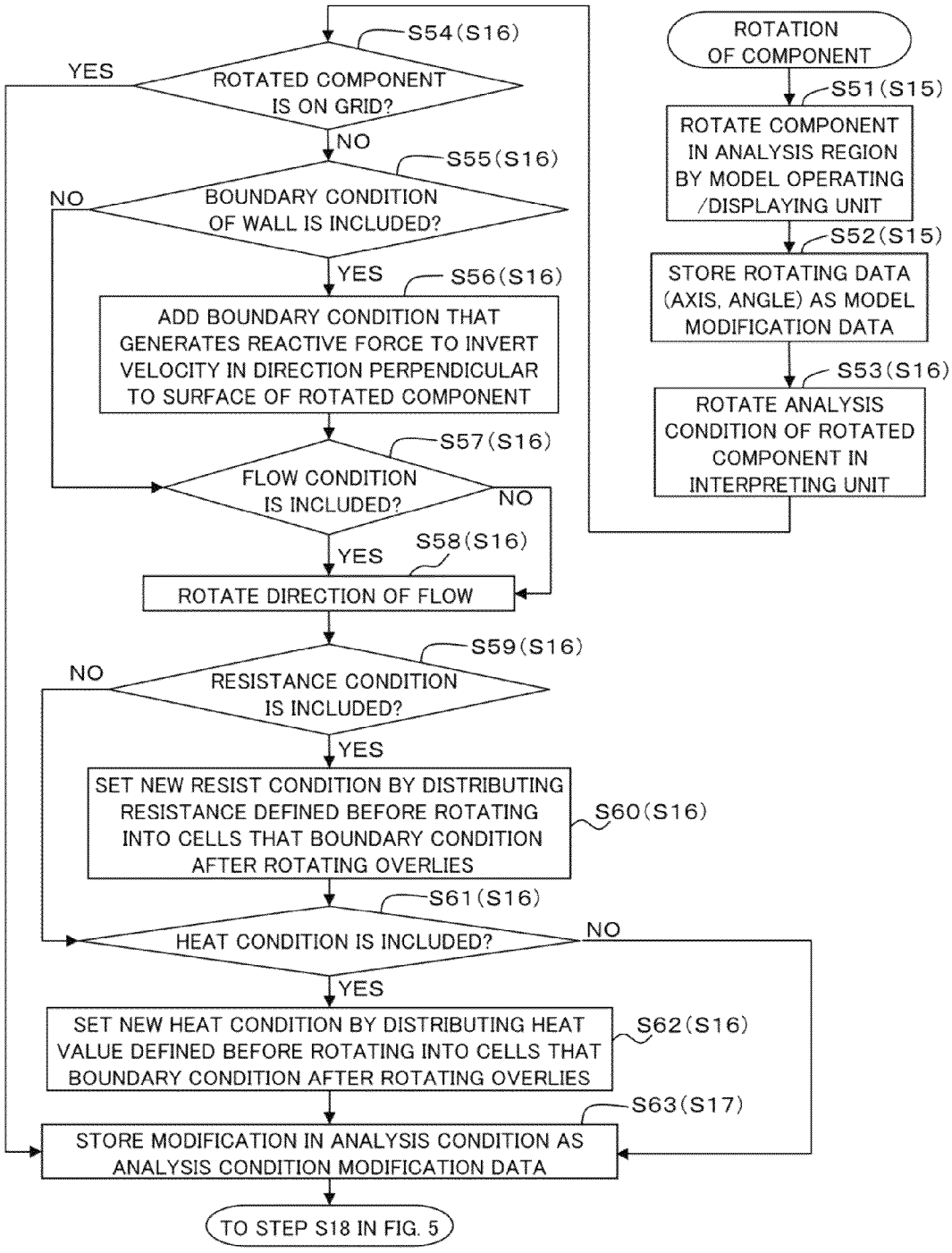

ROTATION OF COMPONENT
S51(S15)
ROTATE COMPONENT IN ANALYSIS REGION BY MODEL OPERATING /DISPLAYING UNIT
S52(S15)
STORE ROTATING DATA (AXIS, ANGLE) AS MODEL MODIFICATION DATA
S53(S16)
ROTATE ANALYSIS CONDITION OF ROTATED COMPONENT IN INTERPRETING UNIT
S54(S16)
ROTATED COMPONENT IS ON GRID?
YES
NO
S55(S16)
BOUNDARY CONDITION OF WALL IS INCLUDED?
NO
YES
S56(S16)
ADD BOUNDARY CONDITION THAT GENERATES REACTIVE FORCE TO INVERT VELOCITY IN DIRECTION PERPENDICULAR TO SURFACE OF ROTATED COMPONENT
S57(S16)
FLOW CONDITION IS INCLUDED?
NO
YES
S58(S16)
ROTATE DIRECTION OF FLOW
S59(S16)
RESISTANCE CONDITION IS INCLUDED?
NO
YES
SET NEW RESIST CONDITION BY DISTRIBUTING RESISTANCE DEFINED BEFORE ROTATING INTO CELLS THAT BOUNDARY CONDITION AFTER ROTATING OVERLIES
S60(S16)
S61(S16)
HEAT CONDITION IS INCLUDED?
NO
YES
SET NEW HEAT CONDITION BY DISTRIBUTING HEAT VALUE DEFINED BEFORE ROTATING INTO CELLS THAT BOUNDARY CONDITION AFTER ROTATING OVERLIES
S62(S16)
S63(S17)
STORE MODIFICATION IN ANALYSIS CONDITION AS ANALYSIS CONDITION MODIFICATION DATA
TO STEP S18 IN FIG. 5

FIG. 9A

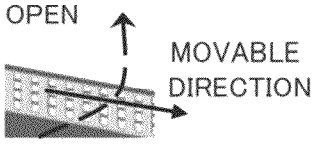


FIG. 9B

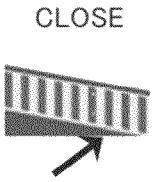


FIG. 10

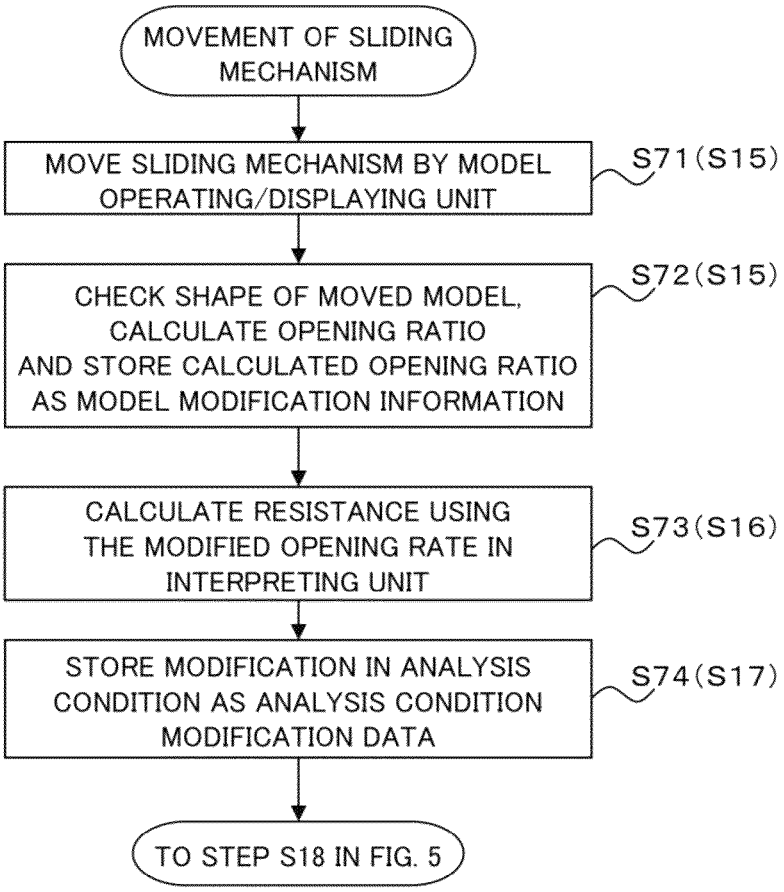
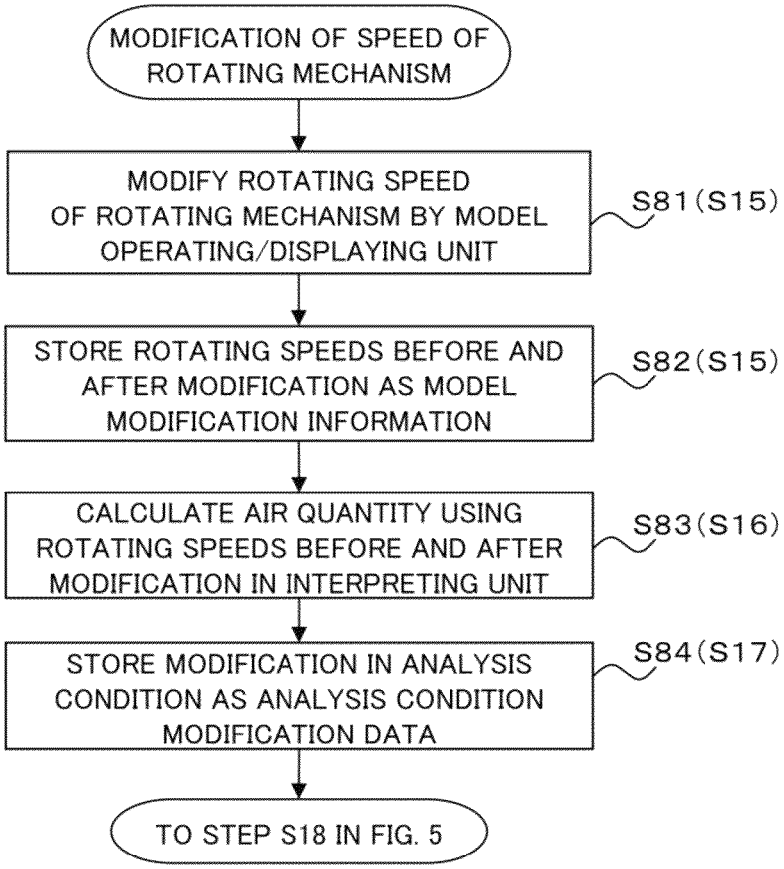

MOVEMENT OF SLIDING MECHANISM
MOVE SLIDING MECHANISM BY MODEL OPERATING/DISPLAYING UNIT
S71(S15)
CHECK SHAPE OF MOVED MODEL, CALCULATE OPENING RATIO AND STORE CALCULATED OPENING RATIO AS MODEL MODIFICATION INFORMATION
S72(S15)
CALCULATE RESISTANCE USING THE MODIFIED OPENING RATE IN INTERPRETING UNIT
S73(S16)
STORE MODIFICATION IN ANALYSIS CONDITION AS ANALYSIS CONDITION MODIFICATION DATA
S74(S17)
TO STEP S18 IN FIG. 5

FIG. 11


MODIFICATION OF SPEED OF ROTATING MECHANISM
MODIFY ROTATING SPEED OF ROTATING MECHANISM BY MODEL OPERATING/DISPLAYING UNIT
S81(S15)
STORE ROTATING SPEEDS BEFORE AND AFTER MODIFICATION AS MODEL MODIFICATION INFORMATION
S82(S15)
CALCULATE AIR QUANTITY USING ROTATING SPEEDS BEFORE AND AFTER MODIFICATION IN INTERPRETING UNIT
S83(S16)
STORE MODIFICATION IN ANALYSIS CONDITION AS ANALYSIS CONDITION MODIFICATION DATA
S84(S17)
TO STEP S18 IN FIG. 5

COMPUTER-READABLE RECORDING MEDIUM IN WHICH THERMAL HYDRAULIC SIMULATION PROGRAM IS STORED, THERMAL HYDRAULIC SIMULATING DEVICE, AND METHOD FOR THERMAL HYDRAULIC SIMULATION

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Application No. 2011-060707 filed on Mar. 18, 2011 in Japan, the entire contents of which are hereby incorporated by reference.

FIELD

The embodiment discussed herein is a thermal hydraulic simulation program that carries out a simulation of a velocity field and a temperature field, a thermal hydraulic simulating device, and a method of thermal hydraulic simulation.

BACKGROUND

In developing a product such as a server and in constructing a structure such as a data center, thermal design takes place in order to determine the proper positions of cooling mechanisms, air-conditioning facilities, and the like. For efficient thermal design, it is important to carry out a thermal hydraulic simulation to grasp the thermal distribution and the flow of air inside an object to be designed beforehand. Namely, before a prototype of an object to be designed is manufactured, a thermal hydraulic simulation is carried out on a computer under analysis condition variously modified by the computer, and on the basis of the results of the simulation under the various conditions, the thermal design can be examined depending on trial and error.

Known simulation schemes are the Software In the Loop Simulation (SILS) that carries out a software simulation to incorporate a handling function into a vehicle and the interactive simulation for a mechanism simulation. In an interactive simulation, when the user makes an operation of an object to be simulated, the result of simulation reflecting the operation is immediately visualized.

However, the above interactive simulation has not been applied to a thermal hydraulic simulation for the following reasons.

Generally, a thermal hydraulic simulation previously sets analysis condition including a boundary condition and other condition and a number of time steps that chronologically continue, and carries out a time series simulation in which the analysis through solving thermal hydraulic equations using the above analysis condition is repeated in the respective time steps. If an analysis condition is modified while such a time series simulation is being carried out, that is, while the analysis of a single time step is being carried out, the analysis using thermal hydraulic equations fails to attain a correct result of simulation.

For the above, in a thermal hydraulic simulation, modification in analysis condition during the analysis needs to previously set time series change in analysis condition, and the result of simulation in which the modification in analysis condition is reflected is obtained through inevitable restarting of the analysis from the first time step. Consequently, it is impossible for the user to immediately reflect a modification in analysis condition, made during the analysis, in the simulation, so that the user does not immediately grasp the influence caused by the modification in analysis condition. Furthermore, to obtain the result of a simulation in which the modification in analysis condition is reflected takes a long processing time.

PRIOR ART REFERENCE

Patent Reference

[Patent Reference 1] Pamphlet of WO2004/025522

[Patent Reference 2] Japanese National Publication of International Patent Application No. 2001-519575

[Patent Reference 3] Japanese Laid-Open Patent Publication No. 2009-134369

[Patent Reference 4] Japanese Laid-Open Patent Publication No. 2000-348214

[Patent Reference 5] Japanese Laid-Open Patent Publication No. 2007-179501

SUMMARY

There is provided a non-transitory computer-readable recording medium in which a thermal hydraulic simulating program that instructs a computer to carry out a simulation of a velocity field and/or a temperature field, the program instructing the computer to execute: carrying out the simulation by solving a thermal hydraulic equation on the basis of an analysis condition in each time step; modifying the analysis condition; after the simulation of a first time step carried out when the analysis condition is modified finishes and before the simulation of a second time step next after the first step starts, referring to the modified analysis condition; and carrying out the simulation based on the modified analysis condition in the second time step.

There is provided a thermal hydraulic simulating device that carries out a simulation of a velocity field and/or a temperature field, the simulator including: a simulating unit that carries out the simulation by solving a thermal hydraulic equation on the basis of an analysis condition in each time step; and a modifying unit that modifies the analysis condition, wherein after the simulation of a first time step carried out when the analysis condition is modified by the modifying unit finishes and before the simulation of a second time step next after the first step starts, the simulating unit refers to the modified analysis condition, and carries out the simulation based on the modified analysis condition in the second time step.

Furthermore, there is provided a method for a thermal hydraulic simulation of a velocity filed and/or a temperature field using a computer, including: carrying out the simulation by solving a thermal hydraulic equation on the basis of an analysis condition in each time step; modifying the analysis condition; after the simulation of a first time step carried out when the analysis condition is modified finishes and before the simulation of a second time step next after the first step starts, referring to the modified analysis condition; and carrying out the simulation based on the modified analysis condition in the second time step.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram schematically illustrating the hardware configuration and the functional configuration of a thermal hydraulic simulating device according to a first embodiment;

FIG. **2** is a diagram illustrating the functional configuration and operation of a thermal hydraulic simulating device of the first embodiment;

FIGS. **3**A and **3**B are diagrams illustrating grid models used in a thermal hydraulic simulation according to the first embodiment;

FIG. **4** is a diagram depicting an outline of operation of a thermal hydraulic simulating device of the first embodiment;

FIG. **5** is a flow diagram illustrating a succession of procedural steps performed in a thermal hydraulic simulating device of the first embodiment;

FIG. **6** is a flow diagram illustrating a succession of procedural steps performed in a thermal hydraulic simulating device of the first embodiment when an attribute of a 3D model is modified;

FIG. **7** is a flow diagram illustrating a succession of procedural steps performed in a thermal hydraulic simulating device of the first embodiment when a component of a 3D model is translated;

FIG. **8** is a flow diagram illustrating a succession of procedural steps performed in a thermal hydraulic simulating device of the first embodiment when a component of a 3D model is rotated;

FIGS. **9**A and **9**B are diagrams illustrating example of displaying of a shutter mechanism of a 3D model in an opening state and a closed state, respectively;

FIG. **10** is a flow diagram illustrating a succession of procedural steps performed in a thermal hydraulic simulating device of the first embodiment when the shutter mechanism of a 3D model is slid; and

FIG. **11** is a flow diagram illustrating a succession of procedural steps performed in a thermal hydraulic simulating device of the first embodiment when a speed of rotation of a rotating mechanism of a 3D model is modified.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, a first embodiment will now be described with reference to the accompanying drawings.

(1) Configuration and Function of a Thermal Hydraulic Simulating Device According to the First Embodiment:

FIG. **1** is a block diagram schematically illustrating the hardware configuration and the functional configuration of a thermal hydraulic simulating device **1** of the first embodiment; and

FIG. **2** is a diagram illustrating the functional configuration and operation of the thermal hydraulic simulating device **1** of the first embodiment.

The thermal hydraulic simulating device **1** carries out a function of simulating a velocity field and/or a temperature field interactively with a user. In order to accomplish the function, the thermal hydraulic simulating device **1** includes an input operating unit **10**, a processor **20**, a memory **30**, and a monitor **40**. Here, the input operating unit **10** is a man-machine interface, which is operated by the user to input various data pieces into the thermal hydraulic simulating device **1** and is exemplified by a mouse and a keyboard. The processor **20** is a CPU (Central Processing Unit). The memory **30** may be an internal memory device such as a RAM (Random Access Memory), a ROM (Read Only Memory), a HDD (Hard Disk Drive), and an SSD (Solid State Drive), or may be an external memory device. The monitor **40** is a display such as a CRT (Cathode Ray Tube), and a LCD (Liquid Crystal Display).

The processor **20** executes a thermal hydraulic simulating program and thereby functions as a model setting unit **21**, a model operating unit **22**, a display controller **23**, an interpreting unit **24**, and a simulating unit **25**, which are to be detailed below.

The memory **30** has memory regions **31**-**35** respectively store 3D model data, model modification data, analysis condition modification data, analysis condition data, and simulation results, as detailed below, and additionally has a region (not illustrated) that stores the thermal hydraulic simulating program.

The monitor **40** displays various information pieces under the control of the display controller **23**, and displays a 3D model represents a space of the velocity field and/or the temperature field to be subjected to the thermal hydraulic simulation on the basis of the 3D model data stored in the memory region **31** (see arrow a**1** in FIG. **2**). The monitor **40** also displays a status of operation (to be detailed below) that the input operating unit **10** and the model operating unit **22** make on the 3D model, and displays results of a thermal hydraulic simulation based on the simulation results stored in the memory region **35** (see arrow a**14** of FIG. **2**).

The model setting unit **21** receives, before a thermal hydraulic simulation starts, various pieces of information that are to be used for the thermal hydraulic simulation and that the user inputs via the input operating unit **10** using the function of a GUI (Graphical User Interface) (see arrow a**2** in FIG. **2**), and stores the received pieces of information into the memory **30**. Using the stored information, the model setting unit **21** determines a 3D model and a thermal hydraulic model that represent the object of a thermal hydraulic simulation.

Here, the various pieces of information that are to be used for a thermal hydraulic simulation and that the model setting unit **21** sets include 3D model data representing a structure to be simulated and analysis condition data that is to be used for the thermal hydraulic simulation of the structure. The 3D model data and the analysis condition data are stored in the memory regions **31** and **34**, respectively (see arrows a**3** and a**4** in FIG. **2**, respectively).

The 3D model data stored in the memory region **31** includes, for example, 3D shape data such as a CAD (Computer Aided Design) model and a mesh model of the structure; setting data of a shutter mechanism and a sliding mechanism such as a sliding door; setting data of a rotating mechanism such as a cooling fan.

The analysis condition data stored in the memory region **34** includes, for example, calculation conditions to be used in the thermal hydraulic simulation, such as a shape model, physical property values, various boundary conditions, heat conditions, convergence conditions, resistance conditions, and flow conditions.

The model setting unit **21** has a function of, upon receipt of such 3D model data and analysis condition data that are input, associating the 3D model data and the thermal hydraulic analyzing model (analysis condition) with each other and storing association information indicating the association between the two models, as 3D model data, in the memory region **31**. If the 3D model consists of a number of elements and/or parts, the above association information makes it possible to associate 3D model data of each element or each part with analysis condition data of the element or the part.

After the user operates the 3D model displayed on the monitor **40** using the GUI function via the input operating unit

10, the model operating unit **22** receives operating data related to the operation (see arrow a**5** in FIG. **2**). The model operating unit **22** then refers to the 3D model data of the 3D model operated by the user which data is stored in memory region **31** (see arrow a**6** in FIG. **2**), obtains model modification data related to the modifying the 3D model due to the operation on the basis of the 3D model data referred-to and the operating data received, and stores the model modification data into the memory region **32** (see arrow a**7** in FIG. **2**). In this embodiment, the model operating unit **22** and the input operating unit **10** collectively function as an operating unit that operates a 3D model displayed on the monitor **40**.

Here, examples of operation made onto a 3D model on the monitor **40** via the input operating unit **10** are the following operations (11)-(13).

(11) operation instructing movement, rotation, addition, deletion, displaying, and canceling displaying of one element (part) consisting of the 3D model. This operation is instructed by, for example, clicking or dragging the mouse (i.e., the input operating unit **10**).

(12) operating modifying operation of a sliding mechanism or a rotating mechanism set in the 3D model. An example of a sliding mechanism is a shutter mechanism (see FIG. **9**) and that of a rotating mechanism is a cooling fan. The modification in operation of a sliding mechanism is instructed by, for example, dragging the mouse (the input operating unit **10**). The modification in the operation of a rotating mechanism is instructed by designating the rotating mechanism to be modified by, for example, clicking the mouse and then inputting the rotating speed after the modification via the keyboard (i.e., the input operating unit **10**).

(13) operation modifying an attribute of the 3D model. Assuming that one of the elements consisting of the 3D model is a heating element, an example of an attribute of the 3D model is a heating value of the heating element. The modification of an attribute is instructed by designating the attribute to be modified through, for example, clicking the mouse and then inputting a desired attribute value to be modified via the keyboard.

The interpreting unit **24** interprets, when a 3D model is modified by the operating units **10** and **22**, the modification data of the 3D model related to the modification of the operating units **10** and **22** into modification data of the analysis condition of the thermal hydraulic simulation, so that the analysis condition is modified. Specifically, the interpreting unit **24** reads the model modification data from the memory region **32** (see arrow a**8** in FIG. **2**), and reads analysis condition data that is associated with the read model modification data from the memory region **34** (see arrow a**9** in FIG. **2**). The interpreting unit **24** calculates modification in the analysis condition data corresponding to the operation of the 3D model on the basis of the read model modification data, the geometrical data of the 3D model, and the analysis condition data. The interpreting unit **24** stores, as analysis condition modification data, the data related to the calculated modification in the analysis condition in the memory region **33** (see arrow a**10** in FIG. **2**). The memory region **34** stores the analysis condition data initially determined while the memory region **33** stores the analysis condition data modified according to the model operation.

The interpreting unit **24** interprets the model operation on the model into corresponding modification of the analysis condition data through, for example, the following processes (21)-(25).

(21) If the operating units **10** and **22** modify an attribute of a 3D model, at least the attribute after the modification is stored, as the model modification data, in the memory region **33**. The interpreting unit **24** refers to the modified attribute stored in the memory region **33** and modifies, based on the modified attribute, a parameter of the analysis condition of the thermal hydraulic simulation, the parameter corresponding to the modified attribute value. The process related to modifying an attribute will be described below with reference to FIG. **6**.

(22) If the operating units **10** and **22** translate a component of a 3D model, an amount (distance, direction) of translating is stored, as the model modification data, in the memory region **33**. The interpreting unit **24** refers to the amount (distance, direction) of the translating stored in the memory region **33** and modifies the position of the boundary condition of the translated component according to the amount (distance, direction) of the translating. If the translated component is not arranged on a grid of the thermal hydraulic analyzing model, the interpreting unit **24** moves the position of the boundary condition of the translated component onto the nearest grid. Conversely, if the position of the boundary condition of the translated component is not arranged onto a grid, the interpreting unit **24** deletes the boundary condition of the translated component and adds another boundary condition that generates a reactive force to invert velocity in a direction perpendicular to the surface of the translated component disposed at a position after the translating to the modification data of the analysis condition. The detailed process related to translation of a component will be described below with reference to FIG. **7**.

(23) If the operating units **10** and **22** rotate a component of a 3D model, data (axis and angle of the rotation) related to the rotating is stored, as the model modification data, in the memory region **33**. The interpreting unit **24** refers to the data (axis and angle of the rotation) related to the rotating stored in the memory region **33**, and modifies the position of the boundary condition of the rotated component through rotating the position of the boundary condition using the same axis and the same angle as those of the rotating of the component. If the rotated component is not arranged on a grid of the thermal hydraulic analyzing model, the interpreting unit **24** deletes the boundary condition of the rotated component and adds another boundary condition that generates a reactive force to invert velocity in a direction perpendicular to the surface of the rotated component disposed at a position after the rotating to the modification data of the analysis condition. The interpreting unit **24** further rotates the direction of flow related to the rotated component, the direction serving as a flow condition, using the same axis and the same angle those of the rotating of the component. Still further, the interpreting unit **24** distributes a resistance and/or a heat value, respectively serving as a resistance condition and/or a heat condition of the rotated component, into one or more cells that the boundary condition after the rotating overlies in accordance with an area ratio or a volume ratio of the cells, and thereby sets the new resistance condition and/or heat condition obtained by the distribution to be the modification data of the analysis condition. The process related to rotation of a component will be detailed below with reference to FIG. **8**.

(24) The operating units **10** and **22** slide a sliding mechanism of a 3D model having an opening ratio in accordance with sliding, the opening ration after the sliding is calculated and stored, as the model modification data, in the memory region **33**. The interpreting unit **24** modifies the resistance value, serving as a resistance condition, corresponding to the sliding mechanism in accordance with the opening ratio after the sliding. The process related to sliding of a sliding mechanism will be detailed below with reference to FIGS. **9** and **10**.

(25) If the operating units **10** and **22** modify an operating speed (rotating speed) of a rotating mechanism of a 3D model, the rotating speeds before and after the rotating are stored, as the model modification data, in the memory region **33**. The interpreting unit **24** refers to the rotating speeds before and after the modifying stored in the memory region **33**, and modifies the analysis condition of the thermal hydraulic simulation related to the rotating mechanism, specifically, a flow condition (air quantity, flow rate) on the basis of the rotating speeds before and after the modification. The process related to modifying an operating speed of a rotating mechanism will be detailed below with reference to FIG. **11**.

The input operating unit **10**, the model setting unit **21**, the model operating unit **22**, the display controller **23**, and the monitor **40** collectively function as a model operating/displaying unit **100** that displays a 3D model in real time and is capable of moving and rotating of a component or a mechanism of the 3D model.

The model operating/displaying unit **100** and the interpreting unit **24** collectively function as a modifying unit **200** that modifies the analysis condition of a thermal hydraulic simulation.

The simulating unit **25** carries out a thermal hydraulic simulation by solving thermal hydraulic equations for each time step on the basis of the analysis condition data and analysis condition modification data respectively stored in the memory regions **34** and **33** (see arrows a**12** and a**11** in FIG. **2**). The simulating unit **25** stores the simulation result exemplified by a speed distribution of a fluid, a temperature distribution, and time in the memory region **35** (see arrow a**13** in FIG. **2**). The simulation result stored in the memory region **35** is displayed on the monitor **40** under the control of the display controller **23** (see arrow a**14** of FIG. **2**), or alternatively may be printed out by a non-illustrated printer.

Known methods of a thermal hydraulic simulation performed by the simulating unit **25** are gird method, particle method, and a grid Bolzmann method. Here, a thermal hydraulic simulation using a grid method is explained. In a normal thermal hydraulic simulation, a time series simulation is conducted in which a number of continuous time steps are set and calculation is repeated in each time step. Calculation of each time step solves the following simultaneous equations (1)-(3) and thereby obtains time evolution of the velocity field and the temperature field. Here, equation (1) corresponds to Navier-Stokes equation that is a nonlinear partial differential equation that describes fluid motion; equation (2) corresponds to continuous formula derived from law of conservation of mass concerning a flow of an incompressible fluid; and equation (3) corresponds to a thermal advection diffusion equation that describes the conduction of heat in the fluid.

$$\dot{u} = -(u \cdot \nabla)u + \nu\nabla^2 u - \frac{1}{\rho}\nabla p + f \tag{1}$$

$$\nabla \cdot u = 0 \tag{2}$$

$$\dot{T} = -(u \cdot \nabla)T + \kappa\nabla^2 T + S \tag{3}$$

In these equations (1)-(3), the symbol "u" represents a rate vector of a fluid; the symbol "p" represents a pressure; the symbol "ρ" represents a density; the symbol "f" represents an external force vector affects per unit weight; the symbol "v" presents a coefficient of kinematic viscosity; the symbol "T" represents temperature; the symbol "K" represents a coefficient of conduction of heat; the symbol "S" represents a heat value received from the outside; and the symbol nabla "∇" represents a space derivative operator. The symbols "u" and "T" with dots on the top in the left sides of the equations (1) and (3) represent partial differences of the rate vector "u" and the temperature "T" with respect to time t, respectively.

In a thermal hydraulic simulation of an incompressible fluid on a computer by solving the above simultaneous partial differential equations (1)-(3), the analysis space is discretized so that the simulating unit **25** discretely calculates differential values. An example of a discretization is to divide the continuous analysis space into grids as depicted in FIGS. **3**A and **3**B. Here, each rectangle or each rectangular parallelepiped defined by grids is referred to as a cell. FIGS. **3**A and **3**B represent grid models used in a thermal hydraulic simulation: specifically, FIG. **3**A represents a two-dimensional grid model; and FIG. **3**B represents a 3D grid model.

The simulating unit **25** of the first embodiment has the following function so that the analysis condition modified by the above modifying unit **200** is immediately reflected in the thermal hydraulic simulation of the ensuing step without restarting the thermal hydraulic simulation from the first time step. Specifically, the simulating unit **25** has a function for, if the modifying unit **200** modifies the analysis condition, referring to the analysis condition modified by the modifying unit **200** at the following referring timing and starting the simulation using the modified condition from the next time step.

The referring timing is after a simulation (analysis) carried out when the analysis condition is modified finishes and before the simulation (analysis) of the next time step starts. Specifically, the thermal hydraulic simulating device **1** of this embodiment separates a time step in which time forwarded by carrying out the analysis from a step in which time is not forwarded, and in a step of not forwarding time, the analysis condition is modified and referred. In other words, even if the analysis condition is modified during the analysis performed in a time step, the modification in the analysis condition is reflected in the thermal hydraulic simulation after completion of analysis of the time step. This function is detailed below with reference to FIG. **5**.

(2) Operation of the Thermal Hydraulic Simulating Device of the First Embodiment:

Next, description will now be made in relation to operation of the thermal hydraulic simulating device **1** of the first embodiment having the above configuration with reference to FIGS. **4**-**11**.

(2-1) Outline of Operation of the Thermal Hydraulic Simulating Device:

FIG. **4** is a diagram depicting an outline of operation of the thermal hydraulic simulating device **1** of the first embodiment. As illustrated in FIG. **4**, the thermal hydraulic simulating device **1** of the first embodiment includes the model operating/displaying unit **100**, the simulating unit **25**, and the interpreting unit **24**. The model operating/displaying unit **100** displays a 3D model on the monitor **40** in real time, and the user is allowed to operate the 3D model, such as moving and rotating, referring to the monitor **40**. Then the interpreting unit **24** generates modification in the analysis condition based on the operation on the 3D model that the user made on the monitor **40** via the input operating unit **10**, and the modification in the analysis condition is to be reflected in the analysis that the simulating unit **25** is to carry out.

The difference between a detailed 3D model that the model operating/displaying unit **100** treats and a thermal hydraulic analyzing model used in the thermal hydraulic simulation makes it impossible to reflect the user operation, without being processed, in the thermal hydraulic simulator.

For the above, the thermal hydraulic simulating device **1** includes the interpreting unit **24** disposed between the model

operating/displaying unit **100** and the simulating unit **25**. Specifically, the interpreting unit **24** interprets operation that the user made on a 3D model via the model operating/displaying unit **100** before or during the analysis conducted by the simulating unit **25** into modification in the analysis condition, so that the modification is immediately reflected in the analysis of the next time step to be carried out by the simulating unit **25**. Thereby, the user can immediately obtain a simulation result in which the operation that the user makes on the 3D model via the model operating/displaying unit **100** is reflected and which is carried out by the simulating unit **25**, so that an interactive thermal hydraulic simulation can be realized.

In the thermal hydraulic simulating device **1**, the modification in the analysis condition corresponding to the operation that the use made on the 3D model is reflected in the thermal hydraulic simulation in the following succession of procedural steps (1) through (4).

(1) The user operates the 3D model via the model operating/displaying unit **100** (see arrow A**1** in FIG. **4**). Specifically, the user instructs movement, rotation, addition, deletion, displaying, and canceling displaying of one element (part) consisting of the 3D model; modifies the operation of a sliding mechanism or a rotating mechanism of the 3D model; or modifies an attribute of the 3D model as described above operations (11)-(13).

(2) The interpreting unit **24** converts the modification in the 3D model by step (1) into modification of the analysis condition associated with to the operated element (see arrow A**2** in FIG. **4**). Here, the 3D model of the model operating/displaying unit **100** is previously associated with the thermal hydraulic analyzing model of the simulating unit **25**.

(3) The modification in the analysis condition in step (2) is reflected in analysis to be carried out by the simulating unit **25** (see arrow A**3** in FIG. **4**), so that the time series simulation is conducted. For this purpose, the simulating unit **25** refers to the analysis condition modification data stored in the memory region **33** after an analysis of a time step being carried out when the analysis condition is modified finishes and before the analysis of the next time step starts, that is, while the time is not forwarded by the simulation. Thereby, the simulating unit **25** can reflect the modified analysis condition in the analysis of the next time step (and subsequent time steps) without restarting the thermal hydraulic simulation from the first time step.

(4) The simulation result stored in the memory region **35** is displayed on the monitor **40** of the model operating/displaying unit **100** (see arrow A**4** in FIG. **4**). The user can confirm and evaluate the simulation result related to the operation made on the 3D model by referring the simulation result displayed on the monitor **40** (see arrow A**5** in FIG. **4**). Consequently, the thermal hydraulic simulating device **1** allows the user to carry out an interactive thermal hydraulic simulation.

(2-2) Succession of Procedural Steps Performed in the Thermal Hydraulic Simulating Device:

Next, description will now be made in relation to a succession of procedural steps performed in the thermal hydraulic simulating device **1**, that is, the procedure of the interactive thermal hydraulic simulation performed in the thermal hydraulic simulating device **1** with reference to the flow diagram (steps S**11**-S**23**) of FIG. **5**.

The model setting unit **21** receives, before a thermal hydraulic simulation starts, various pieces of information that are to be used for the thermal hydraulic simulation and that the user inputs via the input operating unit **10**, and stores the received pieces of information in the memory regions **31** and **34** of the memory **30**. Namely, a 3D model data representing a structure to be simulated is set in the memory region **31**, and analysis condition data used for thermal hydraulic simulation on the structure is set in the memory region **34**. Thereby, the 3D model and the thermal hydraulic model of a structure that is to be subjected to thermal hydraulic simulation are set (step S**11**).

Then the model setting unit **21** associates the 3D model and a thermal hydraulic analyzing model (analysis condition) with each other, and stores, as 3D model data, association data representing the association between the two models in the memory region **31** (step S**12**).

After that, upon the model setting unit **21** receives an instruction of executing the thermal hydraulic simulation input by the user via the input operating unit **10**, the thermal hydraulic simulation starts (step S**13**).

After the start of the simulation, the thermal hydraulic simulating device **1** monitors whether the user modifies the 3D model via the model operating/displaying unit **100** (the operating units **10** and **22**) (step S**14**).

If the 3D model is not modified (No step in step S**14**), the simulating unit **25** refers to the analysis condition data stored in the memory region (step S**18**), and on the basis of the analysis condition data referred, time evolution of the velocity field and the temperature field to be simulated is obtained by solving the above equations (1)-(3) in a single time step (steps S**19** and S**20**).

Conversely, if the 3D model is modified (YES route in step S**14**), the processing of the following steps S**15**-S**20** is to be performed.

First of all, the user modifies the 3D model by operating the input operating unit **10**, for example, the above operations (11)-(13). Upon the model operating unit **22** receives the operating data related to the operating, the 3D model modification data related to the operating is obtained and stored, as the model modification data, in the memory region **32** (step S**15**).

Upon the model modification data is stored in the memory region **32**, the interpreting unit **24** calculates the modification in the analysis condition, which modification corresponds to the model operation, on the basis of the model modification data stored in the memory region **32**, geometrical data of the 3D model, analysis condition data, and others. Namely, the interpreting unit **24** converts the operating data related to operating into the analysis condition of the thermal hydraulic simulation (step S**16**). The result of the conversion by the interpreting unit **24** is stored, as the analysis condition modification data, in the memory region **33**. Consequently, correction and modification in the analysis condition caused by the user operation are reflected in the memory region **33** that is to be referred by the simulating unit **25**, and the corrected and modified analysis condition is reflected in the analysis to be carried out in the next time step (step S**17**).

After that, the simulating unit **25** refers to the analysis condition data and the analysis condition modification data respectively stored in memory regions **34** and **33** (step S**18**). On the basis of the referred analysis condition data and analysis condition modification data, the simulating unit **25** solves the above simultaneous partial differential equations (1)-(3) for a certain time step and thereby obtains time evolution of the velocity field and the temperature filed of a structure to be simulated (steps S**19** and S**20**). The result of the simulation is stored in the memory region **35**.

Upon completion of the thermal hydraulic simulation of a single time step, a determination is made whether now is the timing of displaying the simulation result (step S**21**). The timing of displaying a simulation result is preset in the pre-

determined region of the memory **30**, and when the timing of displaying comes (YES route in step S**21**), the simulation result stored in the memory region **35** is displayed on the monitor **40** under the control of the display controller **23** (step S**22**).

Conversely, when the timing of displaying does not come yet (NO route in step S**21**) or after the simulation result is displayed, a determination is made, on the basis of a termination condition, whether the simulation is to be terminated (step S**23**). The termination condition is that a predetermined time period is elapsed from the start of the simulation or the calculation by the simulating unit **25** comes into a stationary state. If the termination condition is not satisfied and the simulation is not terminated yet (NO route in step S**23**), the procedure performed in the thermal hydraulic simulating device **1** returns to step S**14**. In contrast, if the termination condition is satisfied and the simulation is to be terminated (YES route in step S**23**), the thermal hydraulic simulating device **1** terminates the procedure.

As described above, if modification in the analysis condition is allowed during the analysis of a certain time step, that is, while the above simultaneous partial differential equations (thermal hydraulic equations) (1)-(3) are being solved, the simulation does not attain the correct result.

For the above, the first embodiment divides a conventional single step of a thermal hydraulic simulation into three sub-steps of: reflecting a correction and/or modification in the analysis condition caused by the operation of the user in the memory **30** (step S**17**); referring to the analysis condition modification data (step S**18**); and solving the thermal hydraulic equations (step S**19**). These sub-steps make it possible to refer to the modified analysis condition at the timing of after the analysis carried out when the analysis condition is modified finishes and before the analysis of the next time step starts. Thereby, the analysis condition is corrected and modified, and referred at respective proper timings.

(2-3) Conversion (Interpreting) of User Operation into Analysis Condition:

As described above, the model operating unit **22** modifies the 3D model through operating of the input operating unit **10**, that is, through the above operations (11)-(13) in step S**15**. The modification in the 3D model due to these operations is converted into the modification in the analysis condition of the thermal hydraulic simulation by the interpreting unit **24** in step S**16**. Here, examples of the analysis condition are a boundary condition related to a wall, a flow condition, a resistance condition, and a heat condition. Conversion of a user operation into the analysis condition has a large number of combinations, typical five of which will be detailed below.

(2-3-1) Modification in Attribute:

First, description will now be made in relation to a case where the model operation by the operating units **10** and **22** is a modification of an attribute of the 3D model and the modification of the attribution, in the form of a modification in parameter, is reflected in the thermal hydraulic simulation with reference to a flow diagram (steps S**31**-S**34**) of FIG. **6**. An attribute to be modified here is assumed to be related to a heat value.

Upon an attribute related to a heat value of the 3D model is modified through the model operation (see above operation (13)) by the operating units **10** and **22** (step S**31**), the modified attribute value (numeric value) is stored, as model modification data, in the memory region **33** (step S**32**). The processing of steps S**31** and S**32** correspond to that of step S**15** in FIG. **5**.

The numeric value after the modification stored in the memory region **33** is referred by the interpreting unit **24**, which then modifies the heat value (included in the analysis condition) of the thermal hydraulic analyzing model on the basis of the referred numeric value (step S**33**). The processing of step S**33** corresponds to that of step S**16** of FIG. **5**.

The result of modifying the heat value by the interpreting unit **24** is stored, as analysis condition modification data, in the memory region **33** (step S**34**). Consequently, correction and modification of the heat value of the thermal hydraulic analyzing model due to the user operation are reflected in the memory region **33**, which the simulating unit **25** refers in step S**18**, and thereby the heat value after the correction and modification is reflected in the analysis to be carried out in next time step. The processing of step S**34** corresponds to that of step S**17** in FIG. **5**.

(2-3-2) Translation of a Component:

Next, description will now be made in relation to a case where the model operation by the operating units **10** and **22** is a translation of the 3D model and the translation, in the form of a modification in analysis condition, is reflected in the thermal hydraulic simulation with reference to a flow diagram (steps S**41**-S**48**) of FIG. **7**. This description assumes that a component such as a wall is translated. However, the term "component" throughout the specification includes a structure or a product to be simulated and one of parts and elements constitute such a structure or product.

Upon one of the components of the 3D model is translated within the analyzing region through the model operation (see the above operation (11)) by the operating units **10** and **22** (step S**41**), the amount (distance, direction) of the translating of the model operation is stored, as the model modification data, in the memory region **33** (step S**42**). The processing of steps S**41** and S**42** corresponds to that of step S**15** of FIG. **5**.

The amount (distance, direction) of the translating stored in the memory region **33** is referred by the interpreting unit **24**, which then translates the position of the boundary condition (included in the analysis condition) corresponding to the translated component by the referred distance in the referred direction (step S**43**). The interpreting unit **24** further determines whether the translated component is on a grid of the thermal hydraulic analyzing model (step S**44**).

If the translated component is not on a grid (NO route in step S**44**), the interpreting unit **24** determines whether the boundary condition modified is to be arranged on a grid (step S**45**). Whether a boundary condition is to be arranged on a grid may be predetermined by the user before the simulation starts or may be determined by the user through requesting the user on the monitor **40** in step S**45**.

If the boundary condition is to be arranged on a grid (YES route in step S**45**), the interpreting unit **24** corrects (moves) the position of the boundary condition modified in step S**43** onto the nearest grid (step S**46**). On the other hand, if the boundary condition is not to be arranged on a grid (NO route in step S**45**), the interpreting unit **24** deletes the boundary condition modified in step S**43** and adds a new boundary condition that generates a reactive force to invert the velocity in the direction perpendicular to the surface of the translated component to the analysis condition modification data (step S**47**).

The boundary condition the position of which is moved in step S**46** or the boundary condition added in step S**47** is stored, as the analysis condition modification data, in the memory region **33** (step S**48**).

If the component is on a grid (YES route in step S**44**), the steps S**45**-S**47** are skipped and the boundary condition translated in step S**43** is stored, as the analysis condition modification data, in the memory region **33** (step S**48**).

Storing the analysis condition modification data in step S**48** reflects correction and modification of the boundary con-

dition caused by translation by the user in the memory region **33** that the simulating unit **25** is to refer in step S**18**, and thereby the boundary condition after the correction and the modification is reflected in the analysis to be carried out in the next time step.

The processing of the steps S**43**-S**47** corresponds to that of step S**16** in FIG. **5** and the processing of the step S**48** corresponds to that of step S**17** in FIG. **5**.

If the object translated by the user operation is a group of a number of components, the components are regarded as a single component, which undergoes the above processing.

(2-3-3) Rotation of a Component:

Next, description will now be made in relation to a case where the model operation by the operating units **10** and **22** is rotating of a component of the 3D model and the rotating of the component, in the form of a modification in the analysis condition, is reflected in the thermal hydraulic simulation with reference to a flow diagram (steps S**51**-S**63**) of FIG. **8**.

Upon one of the components of the 3D model is rotated within the analyzing region through the model operation (see the above operation (11)) by the operating units **10** and **22** (step S**51**), rotating data (axis and angle of the rotating) caused by the model operation is stored, as the model modification data, in the memory region **33** (step S**52**). The processing of steps S**51** and S**52** corresponds to that of step S**15** of FIG. **5**.

The rotating data (axis and angle of the rotating) stored in the memory region **33** is referred by the interpreting unit **24**, which then rotates (modifies) the position of the analysis condition corresponding to the component through rotation using the same axis and angle of rotation as the referred axis and angle (step S**53**). The interpreting unit **24** further determines whether the rotated component is on a grid of the thermal hydraulic analyzing model (step S**54**).

If the rotated component is not on a grid (NO route in step S**54**), the interpreting unit **24** determines whether the analysis condition includes a boundary condition related to a wall (step S**55**). If a boundary condition of a wall is included (YES route in step S**55**), the interpreting unit **24** deletes the boundary condition included in the analysis condition modified in step S**53** and adds a new boundary condition that generates a reactive force to invert the velocity in the direction perpendicular to the surface of the rotated component to the analysis condition modification data (step S**56**). If the object rotated by the user operation is a group of a number of components, the components are regarded as a single component, which undergoes the processing of step S**56**.

After the processing of step S**56** finishes or if a boundary condition of a wall is not included (NO route in step S**55**), the interpreting unit **24** further determines whether the analysis condition includes a flow condition (such as a direction of air flow of a cooling fan) (step S**57**). If a flow condition is included (YES route in step S**57**), the interpreting unit **24** modifies the flow condition (i.e., a direction of flow) included in the analysis condition through rotation using the rotating data (axis and angle of rotating) stored in the memory region **33** (step S**58**).

Conversely, after the processing of step S**58** finishes or if a flow condition is not included (NO route in step S**57**), the interpreting unit **24** further determines whether the analysis condition includes a resistance condition (step S**59**). If a resistance condition is included (YES route in step S**59**), the interpreting unit **24** sets a new resistance condition (resistances), as the analysis condition modification data, by distributing the resistance (numeric value) of the resistance condition included in the analysis condition, that is, the resistance defined before the rotating, into cells that the boundary condition after the rotating overlies according to the ratio of areas or volumes of the cells (step S**60**).

After the processing of step S**60** finishes or if a resistance condition is not included (NO route in step S**59**), the interpreting unit **24** determines whether the analysis condition includes heat condition (step S**61**). If a heat condition is included (YES route in step S**61**), the interpreting unit **24** sets a new heat condition (heat amount), as the analysis condition modification data, by distributing a heat value serving as the heat condition included in the analysis condition, that is the heat amount defined before the rotating, to cells that the heat condition after the rotation overlies according to a ratio of areas and volumes of the cells (step S**62**).

The boundary condition added in step S**56**, the flow condition modified in step S**58**, the resistance condition set in step S**60**, and the heat condition set in step S**62** are stored, as the analysis condition modification data, in the memory region **33** (step S**63**).

If the component is on the grid (YES route in step S**54**), the processing of steps S**55**-S**62** is skipped and the analysis condition rotated in step S**53** is stored, as the analysis condition modification data, in the memory region **33** (step S**63**).

Storing the analysis condition modification data in step S**63** reflects correction and modification in the analysis condition due to rotating by the user in the memory region **33**, which the simulating unit **25** is to refer in step S**18**, and thereby reflects the analysis condition after the correction and the modification in the analysis to be carried out in the next time step.

The processing of steps S**53**-S**62** corresponds to that of step S**16** in FIG. **5**, and the processing of step S**63** corresponds to that of step S**17** in FIG. **5**.

(2-3-4) Movement of a Sliding Mechanism:

Next, description will now be made in relation to a case where the model operation by the operating units **10** and **22** is moving of a sliding mechanism of the 3D model and the moving of the sliding mechanism, in the form of a modification in the analysis condition, is reflected in the thermal hydraulic simulation with reference to a flow diagram (steps S**71**-S**74**) of FIG. **10**.

A slide mechanism is a movable mechanism consisting of a movable part and a fixed part, the movable part being movable in a predetermined direction defined with respect to the fixed part. Forming openings on both the movable part and the fixed part makes the sliding mechanism to serve as a shutter mechanism having an opening ratio varying with the sliding movement of the movable part. An opening ratio is a ratio of an area of a hole to the total area of one face.

Here, the sliding mechanism is exemplified by a shutter mechanism as depicted in FIGS. **9**A and **9**B, and is associated with the resistance condition of the thermal hydraulic analyzing model. FIGS. **9**A and **9**B depict examples of displaying the shutter mechanism on the monitor **40**; specifically, FIG. **9**A illustrates an example of displaying the shutter mechanism of the 3D model in an opening state; and FIG. **9**B is an example of the 3D model in a closed state. Besides the shutter mechanism, an example of the sliding mechanism is a sliding door.

Upon the shutter mechanism of the 3D model is moved from the state of FIG. **9**A to the state of FIG. **9**B through the model operation (see above operation (12)) by the operating units **10** and **22** (step S**71**), the opening ratio after the sliding is calculated and stored, as the model modification data, in the memory region **33** (step S**72**). The processing of steps S**71** and S**72** corresponds to the processing of step S**15** in FIG. **5**.

The opening ratio stored in the memory region **33** is referred by the interpreting unit **24**, which modifies the resis-

tance value of the resistance condition associated with the shutter mechanism into the referred opening ratio using the following formula (4) (step S73). The resistance serving as a resistance condition is expressed in the form of a pressure loss Δp in formula (4). On the basis of the referred opening ratio, the interpreting unit **24** modifies the resistance serving as the resistance condition. The processing of step S73 corresponds to that of step S16 of FIG. **5**.

$$\Delta p = \frac{1}{2} f_0 A^2 \rho v^2 \quad (4)$$

In this formula, the term "v" represents a velocity of the fluid; the term "A" represents an opening ratio; and the term "f_0" represents a pressure loss in the absence of resistance.

The modified resistance condition (resistance) is stored, as the analysis condition modification data, in the memory region **33** (step S74). Consequently, the correction and the modification in the resistance serving as the resistance condition, which correction and modification are caused by moving the sliding mechanism by the user, are reflected in the memory region **33**, which the simulating unit **25** is to refer in step S18, and thereby the resistance corrected and modified is reflected in the analysis to be carried out in the next time step. The processing of step S74 corresponds to that of step S17 in FIG. **5**.

(2-3-5) Modification of the Speed of Rotating Mechanism:

Next, description will now be made in relation to a case where the model operation by the operating units **10** and **22** is a modification of an operating speed (rotating speed) of a rotating mechanism of the 3D model and the modification in operation speed, in the form of a modification of the analysis condition, is reflected in the thermal hydraulic simulation with reference to a flow diagram (steps S81-S84) of FIG. **11**. A rotating mechanism has a configuration in which a movable part rotates around a single axis. Here, the rotating mechanism is exemplified by a cooling fan, and is associated with the flow condition of the thermal hydraulic analyzing model.

Upon the rotating speed of a cooling fan of the 3D model is modified through the model operation (see the above operation (12)) by the operating units **10** and **22** (step S81), the rotating speeds w_1 and w_2 of the rotating mechanism before and after the modification are stored, as the model modification data, in the memory region **33** (step S82). Specifically, the symbol w_1 represents the rotating speed before the modification and the symbol w_2 represents the rotating speed after the modification. The processing of steps S81 and S82 corresponds to that of step S15 of FIG. **5**. This description assumes that the model operation rotates the cooling fan, being rotating at the rotating speed w_1, at the rotating speed w_2. Providing that the air quantity before the modification in the rotating speed is represented by V_1, the air quantity after the modification V_2 is represented by the following formula (5).

$$V_2 = \frac{w_2}{w_1} V_1 \quad (5)$$

The rotating speeds w_1 and w_2 before and after the modification stored in the memory region **33** are referred by the interpreting unit **24**, which modifies the air quantity (i.e. amount of flow) serving as the flow condition of the cooling fan, using the above formula (5) based on the rotating speeds w_1 and w_2 before and after the modification (step S83). The processing of step S83 corresponds to that of step S16 of FIG. **5**. Alternatively, if the interpreting unit **24** grasps the properties of the cooling fan, such as a rotating speed, an air quantity, and a pressure loss between the rear and the front of the cooling fan, the interpreting unit **24** may calculate the air quantities after the modification using the curve expressing the properties.

The modified flow condition (air quantity) is stored, as the analysis condition modification data, in the memory region **33** (step S84). Consequently, the correction and the modification in the air quantity serving as the flow condition, which correction and modification are caused by modification of the rotating speed by the user, are reflected in the memory region **33**, which the simulating unit **25** is to refer in step S18, and thereby the air quantity corrected and modified is reflected in the analysis to be carried out in the next time step. The processing of step S84 corresponds to that of step S17 in FIG. **5**.

(3) Effects of the Thermal Hydraulic Simulating Device of this Embodiment:

In the thermal hydraulic simulating device **1** of the first embodiment, if the analysis condition is modified by the modifying unit **200**, the analysis condition modification data is referred at the timing (i.e. in the step during which time is not forwarded) after the analysis in the time step carried out when the analysis condition is modified and before the analysis to be carried out in the next time step, and the thermal hydraulic simulation is carried out on the basis of the referred analysis condition modification data. Thereby, modification in the analysis condition through the user operation is immediately reflected in performing of the thermal hydraulic simulation. Namely, the analysis condition modified by the model operating/displaying unit **100** and the interpreting unit **24** is immediately reflected in the thermal hydraulic simulation to be carried out in the next time step without restarting the thermal hydraulic simulation from the first time step.

According to the thermal hydraulic simulating device **1** of the first embodiment, upon the user makes an operation on the 3D model through the model operating/displaying unit **100**, the result of the simulation in which the user operation is reflected is immediately visualized on the monitor **40**. Consequently, the thermal hydraulic simulating device **1** enables an interactive thermal hydraulic simulation.

As the above, since a detailed 3D model that the model operating/displaying unit **100** deals is normally different from a thermal hydraulic analyzing model used in the thermal hydraulic simulation, it is impossible to directly reflect the user operation, without being modified, in the thermal hydraulic simulator. To solve this problem, the thermal hydraulic simulating device **1** disposes the interpreting unit **24** between the model operating/displaying unit **100** and the simulating unit **25**. The operation that the user makes on the 3D model via the model operating/displaying unit **100** before or during the analysis by the simulating unit **25** is converted into a modification in the analysis condition by the interpreting unit **24** and is thereby immediately reflected in the analysis to be carried out in the next time step. This makes the user possible to immediately obtain the result of the simulation that the simulating unit **25** carries out on the basis of modification in the 3D model that the user makes via the model operating/displaying unit **100**, so that an interactive thermal hydraulic simulation can be realized. Accordingly, in developing a product such as a server and in constructing a structure such as a data center, efficient thermal design can be realized.

(4) Others:

A preferred embodiment of the present invention is detailed as the above. However, the present invention is by no

means limited to the first embodiment and may be variously modified without departing the gist of the present invention.

The entire function or a part of the function of the model setting unit **21**, the model operating unit **22**, the display controller **23**, the interpreting unit **24**, and the simulating unit **25** is realized by a computer (such as a CPU, an information processor, and various terminals) executing one or more predetermined application program (thermal hydraulic simulating program).

The programs may be provided in the form of being stored in a computer-readable recording medium, such as a flexible disk, a CD (e.g., CD-ROM, CD-R, CD-RW), a DVD (e.g., DVD-ROM, DVD-RAM, DVD-R, DVD-RW, DVD+R, DVD+RW), and a Blu-ray disc. In this case, a computer reads the programs from the recording medium and sends the read programs to an internal or external memory to store for use.

Here, a computer is a concept of a combination of hardware and an OS (Operating System), and means hardware which operates under control of the OS. Otherwise, if an application program operates hardware independently of an OS, the hardware corresponds to the computer. Hardware includes at least a microprocessor such as a CPU and means to read a computer program recorded in a recording medium. The thermal hydraulic simulation program contains a program code that causes the above computer to realize the functions of the model setting unit **21**, the model operating unit **22**, the display controller **23**, the interpreting unit **24**, and the simulating unit **25**. Part of the functions may be realized by the OS, not by the application program.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiment(s) of the present invention has(have) been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A non-transitory computer-readable recording medium in which a thermal hydraulic simulating program that instructs a computer to carry out a simulation of a velocity field and/or a temperature field, the program instructing the computer to execute:

carrying out the simulation by solving a thermal hydraulic equation on the basis of an analysis condition in each time step;

modifying the analysis condition;

when the analysis condition is modified while the simulation is being carried out, storing data related to the modified analysis condition in a memory region;

after completion of the simulation in a first time step being carried out at the modifying the analysis condition and before start of the simulation in a second time step after the first time step, referring to the data related to the modified analysis condition stored in the memory region;

carrying out the simulation based on the data related to the modified analysis condition in the second time step;

displaying a three-dimensional (3D) model representing a space including the velocity field and/or the temperature field on a monitor; and

if a sliding mechanism having an opening ratio varying with sliding of the sliding mechanism is slid on the 3D model displayed on the monitor,

modifying a resistance, serving as a resistance condition of the sliding mechanism and included in the analysis condition, in accordance to the opening ratio varied through the sliding.

2. The non-transitory computer-readable recording medium according to claim **1**, the program instructing the computer to further execute:

if a component of the 3D model displayed on the monitor is translated,

modifying a position of a boundary condition, associated with the translated component and included in the analysis condition, in accordance with a distance and a direction of the translating.

3. The non-transitory computer-readable recording medium according to claim **2**, the program instructing the computer to further execute:

if the translated component is not arranged on a grid of a thermal hydraulic analyzing model,

moving the position of the boundary condition associated with the translated component onto a nearest grid.

4. The non-transitory computer-readable recording medium according to claim **2**, the program instructing the computer to further execute:

if the translated component is not arranged on a grid of a thermal hydraulic analyzing model,

deleting the boundary condition associated with the translated component; and

adding a second boundary condition, that generates a reactive force to invert a velocity in a direction perpendicular to a surface of the translated component disposed at a position after the translating, to the modification data of the analysis condition.

5. The non-transitory computer-readable recording medium according to claim **1**, the program instructing the computer to further execute:

if a component of the 3D model displayed on the monitor is rotated,

modifying a position of a boundary condition, associated with the rotated component and included in the analysis condition, through rotating the position of the boundary condition using an axis and an angle of rotation same as those of rotating of the rotated component.

6. The non-transitory computer-readable recording medium according to claim **5**, the program instructing the computer to further execute:

if the rotated component is not arranged on a grid of a thermal hydraulic analyzing model,

deleting the boundary condition associated with the rotated component; and

adding a second boundary condition, that generates a reactive force to invert a velocity in a direction perpendicular to a surface of the rotated component disposed at a position after the rotating, to the modification data of the analysis condition.

7. The non-transitory computer-readable recording medium according to claim **1**, the program instructing the computer to further execute interpreting data about the modifying related to the operating on the 3D model into modification data of the analysis condition and storing the modification data as the data related to the modified analysis condition in the memory region.

8. A thermal hydraulic simulating device that carries out a simulation of a velocity field and/or a temperature field, the thermal hydraulic simulating device comprising:

a processor, a memory, and a monitor, wherein the processor

carries out the simulation by solving a thermal hydraulic equation on the basis of an analysis condition in each time step;

modifies the analysis condition;

when the analysis condition is modified while the simulation is being carried out, stores data related to the modified analysis condition in a memory region in the memory;

after completion of the simulation in a first time step being carried out at the time of the modifying the analysis condition and before the start of the simulation in a second time step next after the first time step, refers to the data related to the modified analysis condition stored in the memory region, and carries out the simulation based on the data related to the modified analysis condition in the second time step;

displays a three-dimensional (3D) model representing a space including the velocity field and/or the temperature field on the monitor; and

if a sliding mechanism having an opening ratio varying with sliding of the sliding mechanism is slid on the 3D model displayed on the monitor,

modifies a resistance, serving as a resistance condition of the sliding mechanism and included in the analysis condition, in accordance to the opening ratio through the sliding.

9. The thermal hydraulic simulating device according to claim **8**, wherein if a component of the 3D model displayed on the monitor is translated,

the processor modifies a position of a boundary condition, associated with the translated component and included in the analysis condition, in accordance with a distance and a direction of the translating.

10. The thermal hydraulic simulating device according to claim **9**, wherein if the translated component is not arranged on a grid of a thermal hydraulic analyzing model,

the processor moves the position of the boundary condition associated with the translated component onto a nearest grid.

11. The thermal hydraulic simulating device according to claim **9**, wherein, if the translated component is not arranged on a grid of a thermal hydraulic analyzing model,

the processor deletes the boundary condition associated with the translated component, and adds a second boundary condition, that generates a reactive force to invert a velocity in a direction perpendicular to a surface of the translated component disposed at a position after the translating, to the modification data of the analysis condition.

12. The thermal hydraulic simulating device according to claim **8**, wherein if a component of the 3D model displayed on the monitor is rotated,

the processor modifies a position of a boundary condition, associated with the rotated component and included in the analysis condition, through rotating the position of the boundary condition using an axis and an angle of rotation same as those of rotating of the rotated component.

13. The thermal hydraulic simulating device according to claim **12**, wherein, if the rotated component is not arranged on a grid of a thermal hydraulic analyzing model,

the processor deletes the boundary condition associated with the rotated component, and adds a second boundary condition, that generates a reactive force to invert a velocity in a direction perpendicular to a surface of the rotated component disposed at a position after the rotating, to the modification data of the analysis condition.

14. The thermal hydraulic simulating device according to claim **12**, wherein the processor rotates a direction of flow, serving as a flow condition associated with the rotated component and included in the analysis condition, through rotating the position of the boundary condition using the axis and the angle of rotation same as those of rotating of the rotated component.

15. The thermal hydraulic simulating device according to claim **14**, wherein the processor distributes a resistance and/or a heat value, respectively serving as a resistance condition and/or the heat condition associated with the rotated component and included in the analysis condition, to one or more cells that the boundary condition of the rotated component overlies in accordance with an area ratio or a volume ratio of the cells to thereby generate a second resistance condition and/or a second heat condition, and set the second resistance condition and/or the second heat condition to be the modification data of the analysis condition.

16. The thermal hydraulic simulating device according to claim **8**, wherein the processor translates data about the modifying related to the operating on the 3D model into modification data of the analysis condition and stores the modification data as the data related to the modified analysis condition in the memory region.

17. A method for a thermal hydraulic simulation of a velocity filed and/or a temperature field using a computer, comprising:

carrying out the simulation by solving a thermal hydraulic equation on the basis of an analysis condition in each time step;

modifying the analysis condition;

when the analysis condition is modified while the simulation is being carried out, storing data related to the modified analysis condition in a memory region;

after the completion of the simulation in a first time step being carried out at the time of the modifying the analysis condition and before the start of the simulation in a second time step next after the first time step, referring to the data related to the modified analysis condition stored in the memory region;

carrying out the simulation based on the data related to the modified analysis condition in the second time step;

displaying a three-dimensional (3D) model representing a space including the velocity field and/or the temperature field on a monitor; and

if a sliding mechanism having an opening ratio varying with sliding of the sliding mechanism is slid on the 3D model displayed on the monitor,

modifying a resistance, serving as a resistance condition of the sliding mechanism and included in the analysis condition, in accordance to the opening ratio through the sliding.

18. The method according to claim **17** further comprising interpreting data about the modification related to the operating on the 3D model into modification data of the analysis condition and-storing the modification data as the data related to the modified analysis condition in the memory region.

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